

CHAPTER 7

GEOMETRIC DESIGN

7-1. Roadway Cross Section.

a. Right-of-Way Width. The right-of-way (or roadway) must be wide enough to accommodate the track, side ditches, portions of embankment or cut slopes, parallel service roads, and other structures and facilities necessary for the operation of the railroad. Figures 6-5 through 6-11 indicate the width required for the basic track structure.

b. Snow Allowance. In areas with heavy snowfall, additional roadway width (or ditch width) may be useful to provide sufficient room for snow plowed from the track.

7-2. Grades and Track Profile.

a. Grades. Gradient criteria for main running tracks are given in paragraph 3-3. Gradient criteria for terminal areas are given in paragraph 8-3.

b. Vertical Curves. Vertical curves are required as a transition between different grades. Transition rates are different for summits and sags. Here, summit refers to a convex curve where an ascending grade changes to a flatter grade, where a descending grade changes to a steeper grade, or where an ascending grade changes to a descending grade. Sags are concave curves which occur where an ascending grade changes to steeper grade, a descending grade changes to flatter grade, or where a descending grade changes to an ascending grade. (Note: It is best to avoid locating turnouts in vertical curves.) Table 7-1 shows recommended transition rates between grades. The length of track required for these transitions is determined from equation 7-1.

Table 7-1. Recommended Transition Rates Between Grades on Main Running Tracks.

Summits	Sags	
0.1	0.05	Minimum rate needed: Use where speeds will exceed 15 MPH and right-of-way length is ample.
0.2	0.1	Average rate: Use where speeds will not exceed 15 MPH or where transition length is limited.
0.3	0.15	Maximum rate where speeds will exceed 15 MPH.
0.4	0.2	Maximum rate where speeds will not exceed 15 MPH.

Note: Figures are given as percent change in grade per 100 feet of track length.

$$L = \frac{G_1 - G_2}{r} \times 100 \quad (\text{eq 7-1})$$

L = Length of track required for vertical curve (ft). G₁ and G₂ = slope of the two adjacent grades (percent), where ascending grades have a positive value and descending grades have a negative value. r = Rate of change in grade in 100 feet. (For main running tracks, use table 7-1. For terminal tracks, also (see para 8-3).

c. Track Profile. On either main running tracks or terminal tracks, a rolling profile (frequent changes in gradient) in the roadbed or in the final track surface (top of rail elevation) is undesirable. The criteria in table 3-2 should be followed to maintain an acceptably smooth track profile.

7-3. Horizontal Curves.

a. Definition. Railroads are laid out with circular curves using the chord definition. Curvature is measured in degrees, as indicated in equation 7-2.

D = Degree of curve (decimal degrees).

R = Radius of curve (feet).

b. Design Criteria.

(1) Design categories for curves on main running tracks are shown in table 3-3; for terminals, also use section 8-3.

(2) During the design of major track rehabilitation projects, it is recommended that, where practical, existing curvature above 10 degrees for main running tracks and 12 degrees in terminal areas be reduced below these limits.

c. Minimum Tangent Length Between Reverse Curves. When curves of different directions immediately follow each other (reverse curves) there must be a length of tangent track between the two curves to avoid train operating difficulties. The minimum tangent lengths between reverse curves are:

Degree of Curve	Minimum Tangent Length
06	60ft
6-12	100 ft

d. Superelevation.

(1) For either new design or major rehabilitation, the outer rail in curves should be elevated above the inner rail by the amount shown in table 7-2. Designs should not call for a combination of speed and curvature which fall below the bottom stepped ledger line in the table.

Table 7-2. Design Superelevation for Curved Track.

Degree of Curvature	Maximum Operating Speed, mph						
	10	15	20	25	30	35	40
0.50							
1.00							
1.50							1.0
2.00						1.0	1.0
2.50					1.0	1.0	1.5
3.00					1.0	1.5	2.0
3.50				1.0	1.0	2.0	2.5
4.00				1.0	1.5	2.0	3.0
4.50			1.0	1.0	1.5	2.5	3.5
5.00			1.0	1.0	1.5	2.5	
5.50			1.0	1.5	2.0		
6.00			1.0	1.5	2.0		
6.50			1.0	1.5			
7.00			1.0	2.0			
7.50			1.0				
8.00			1.5				
8.50							
9.00							
9.50							
10.00							
10.50							
11.00							
11.50							
12.00							

Note: Table entries are superelevation in inches.

(2) Full superelevation must be provided around the entire curve. For curves with 1-inch superelevation, that elevation may be run out (transitioned back to level) in 40 feet of tangent at the beginning and end of the curve. Where superelevation is more than 1 inch, spirals will be provided at each end of the curve.

e. Spirals.

(1) When, used, spiral transition curves will be designed as shown in the AREA manual. Superelevation will uniformly increase from zero at the beginning of the spiral (at the tangent) to the full elevation at the end of the spiral (where full curvature is reached).

(2) Spiral length will be determined from equation 7-3.

$$L_s = 40 \times S \quad (\text{eq 7-3})$$

L_s = Length of spiral (feet).

S = Full superelevation (inches).

f. Increase in Gage on Very Sharp Curves. Where curves of 12 degrees or more cannot be avoided, finished track gage will be as follows:

Curvature Range (degrees)	Track Gage (Inches)
12 to 14	56 5/8
14 to 16	56 3/4

7-4. Turnouts.

a. Introduction. Structural design of turnouts and design options are covered in paragraph 6-14, which should be used in combination with this section for complete turnout selection and specification.

b. Size.

(1) Turnout size is designated by the size of the frog used in the turnout, as illustrated in figure 7-1. The size of the frog determines the

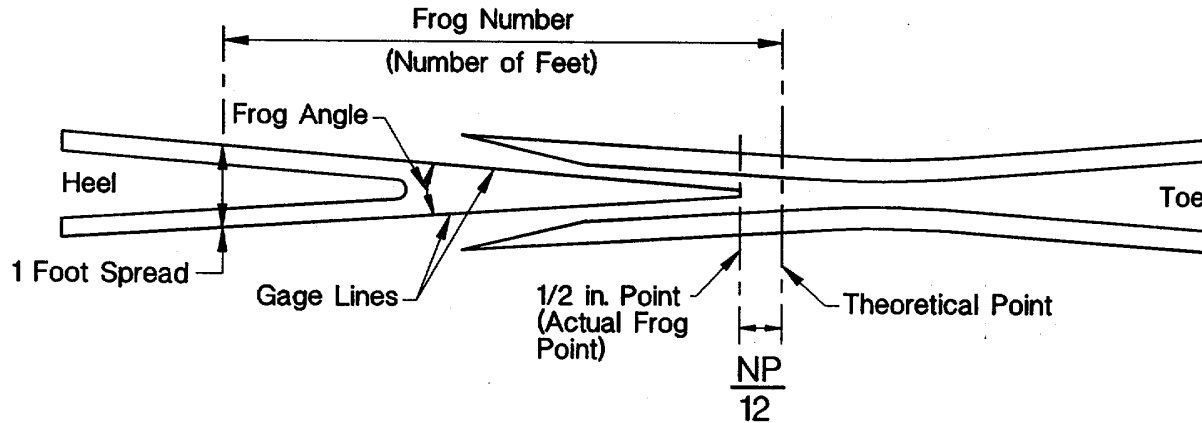


Figure 7-1. Determining Frog Number (Turnout Size).

angle at which the turnout track diverges from the tangent track. Frog size also influences the required degree of curvature within the turnout.

(2) Turnout size should be selected according to table 7-3.

Table 7-3. Turnout Size Selection Criteria.

Turnout Size	Turnout Curvature (degrees)	Selection Criteria
10	7.4	Preferred where space permits, or where long cars (over 75 feet) or 140-ton flatcars (with 3-axle trucks) are being handled Use for crossovers.
9	9.3	Smallest size recommended for handling long cars (over 75 feet) or 140-ton flatcars (with 3-axle trucks). In ladder tracks, saves space compared to a number 10.
8	11.8	Not recommended for handling long cars (over 75 feet) or 140-ton flatcars (with 3-axle trucks). Smallest size normally permitted.

c. Layout Data and Dimensions.

(1) In most cases, designers will use the dimensions and layout data for standard turnouts shown in AREA Plans 910 and 911. Turnouts may be laid out as left-hand, right-hand, or equilateral, as shown in figure 6-23.

(2) On occasions, when non-standard layout is required, or where different point lengths are used, turnout layout may be determined from figure 7-2 and equations 7-4 through 7-7.

$$\frac{h-t}{\sin s} = \quad (\text{eq 7-4})$$

S = Switch angle (degrees).

h = heel spread (inches). (Standard dimension is 6.25 inches).

t = thickness of switch point (inches). (Standard dimension is 0.25 inches).

a = length of switch point (inches).

C = Long chord (feet).

q = g - e - h (feet), where g is track gage, e is frog toe spread from AREA Plan 910, Column 21, and h is the switch heel spread distance (which has a standard value of 0.52 feet).

F = Frog angle (degrees), from AREA Plan 910, Column 17 (converted to degrees).

S = Switch angle (degrees).

$$r \sim \frac{C}{2 \sin 1/2 (F - S)} \quad (\text{eq 7-6})$$

R = Radius of curved closure rail (feet).

C = Long chord (feet).

F = Frog Angle (degrees)

S = Switch Angle (degrees).

L = a + C + d (eq 7-7)

L = Lead ((feet).

a = Switch length (feet).

C = Long chord (feet).

d = Frog toe length, from AREA Plan 910, Column 19 (feet).

d. *Equilateral Turnouts.* In an equilateral turnout, the diverging angle (frog angle) is divided equally on both sides, thus the turnout has two curved stock rails and two curved closure rails which mirror each other. Likewise, the degree of curve along each closure rail is half that of a standard left or right-hand turnout.

e. Turnouts on the Inside of a Curve.

(1) When not required by space limitations or other local conditions, turnouts to the inside of a curve will be avoided.

(2) Curvature through a turnout on the inside of a curve equals the degree of curvature for the curve plus that for a standard turnout. Thus, a number 10 turnout off the inside of a 3 degree curve will have a curvature of 3 + 7.4 = 10.4 degrees. The total curvature must not exceed design limits.

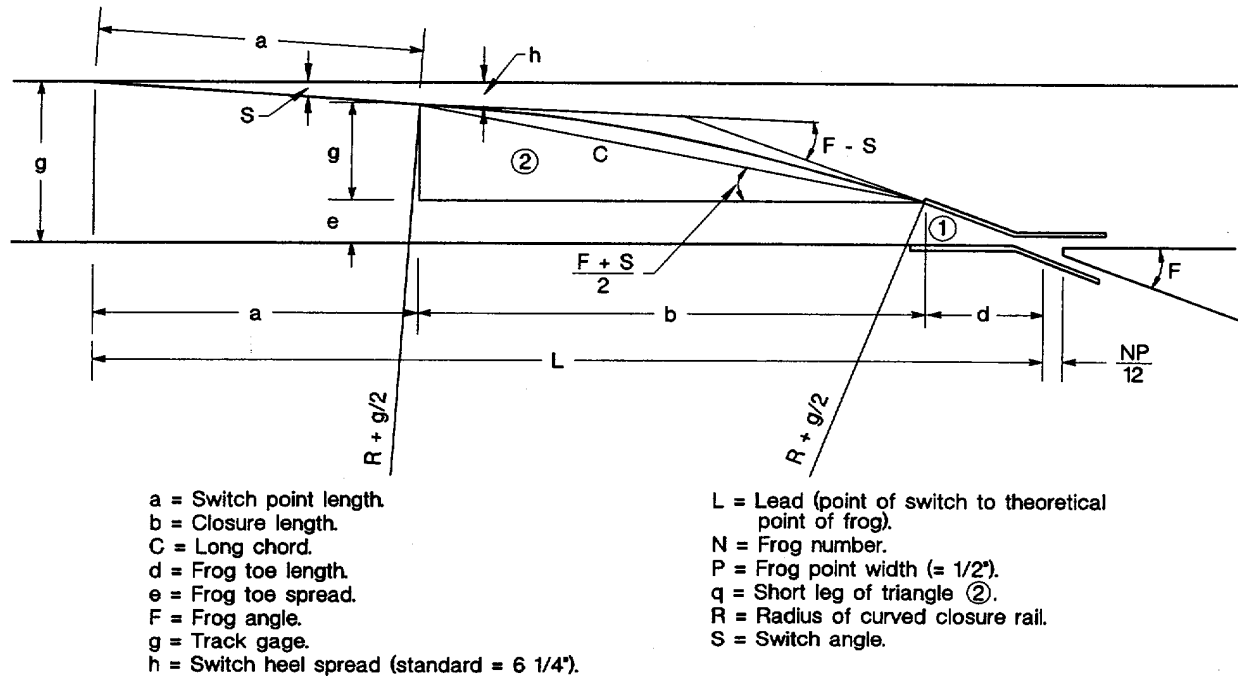


Figure 7-2. Turnout Design.

7-5. Track Connections and Ladder Tracks.

a. Diverging Routes.

(1) Figure 7-3 shows the layout for a typical diverging route connection. Note that the angle that the route diverges is the same as the frog angle for the turnout. The distance from the intersection of track center lines to the location of the frog point is given by equation 7-8.

$$BK = g(N) + 24 \quad (\text{eq 7-8})$$

BK = Distance from points B to K, as shown in figure 7-3 (feet).

g = Track gage (feet).

N = Frog number.

(2) For layout of parallel siding connections, as shown in figure 7-4, the tangent distance Q should be at least 50 feet.

b. Crossovers. Crossovers are a combination of two turnouts used to join two adjacent tracks, as shown in figure 6-23.

c. Ladder Tracks. Figure 7-5 illustrates a typical ladder track, shown between points A and H. This arrangement is commonly used for parallel yard tracks or loading tracks. (Also see chapter 8 for layout of yard and terminal tracks).

7-6. Clearances.

a. Clearances Will Be Checked. For either new construction or rehabilitation work, the location and position of all tracks will be checked for

proper clearances before the final design is prepared and after construction is complete. Allowances will be provided for future track surfacing (adding ballast and raising track) and for small k' changes in alignment during maintenance.

b. Recommended Minimum. Minimum clearances are shown in figure 7-6 and table 7-4. Vertical clearances are measured from the top of the rail, and horizontal clearances are measured from the center line of track.

c. State Requirements. Each state has legal requirements for railroad clearances. These are summarized in a table in chapter 28, section 3.6 of the AREA Manual. Where a state requires greater clearances than shown in figure 7-6 or table 7-4 the state requirement will be met.

d. Curved Track. For each degree of curvature, side clearances will be increased 1-1/2 in. over that required in figure 7-6 and table 7-4. When an obstruction is located adjacent to tangent track, but the track begins to curve within 80 ft of the obstruction, the side clearances shall be increased by the following amounts:

Distance from Obstruction to Curved Track, feet	Increase Per Degree of Curvature, inches
0-20	1-1/2
21-40	1-1/8
41-60	3/4
61-80	3/8

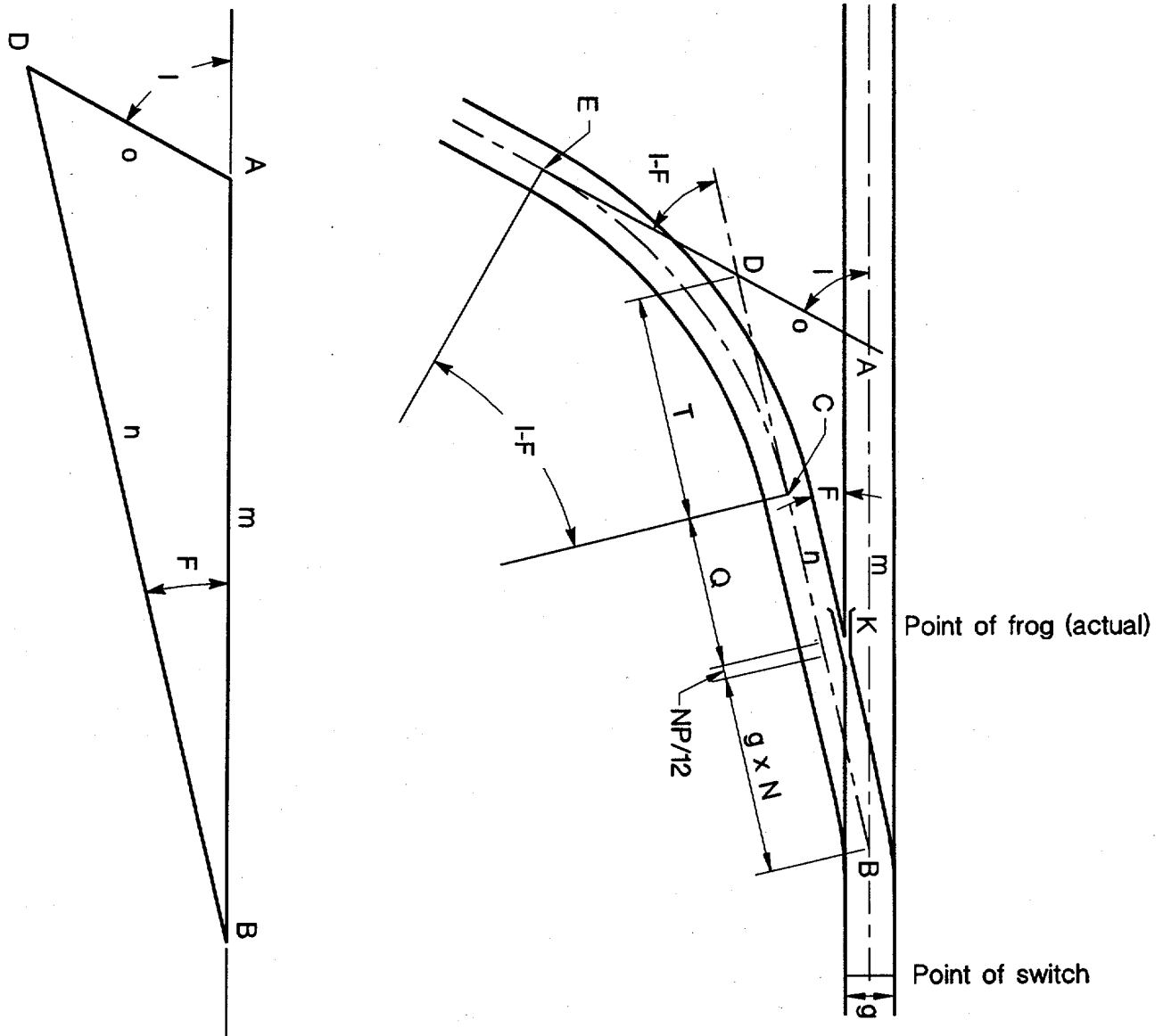


Figure 7-3. Diverging Route Connection.

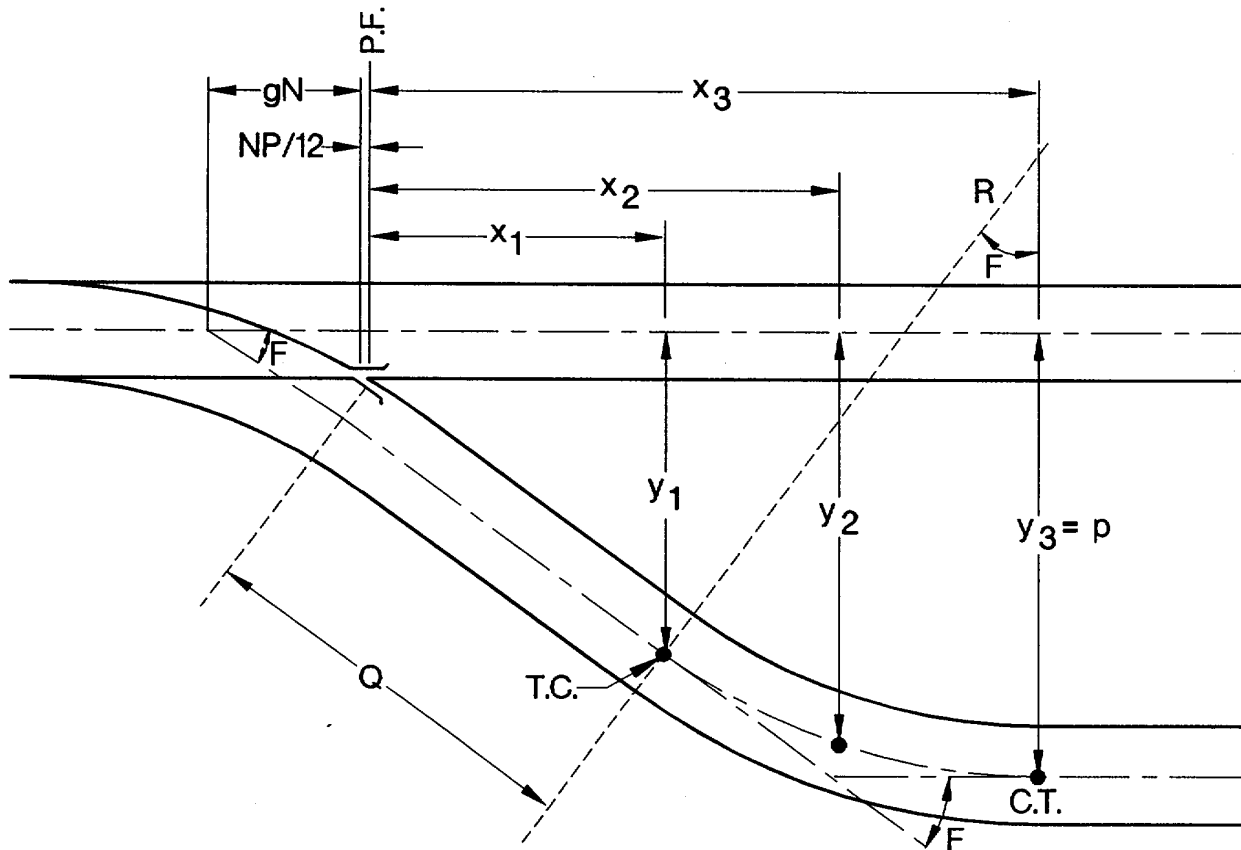


Figure 7-4. Parallel Siding Connection.

e. *Minimum Track Centers.* The recommended minimum distance between the center lines of adjacent tracks is as follows:

Between:	Minimum Distance Between Center Lines (feet)
Main tracks	15
Siding or yard track and main	15
Yard of storage tracks	14 (15, if space permits)

f. *Clearance Points At Turnouts, Ladder Tracks, and Crossings.*

(1) Figure 7-7 shows how to determine the location of clearance points at turnouts, ladder tracks, and rail crossings. As no car or piece of equipment may be left standing on a track with any part of it extending past the clearance point (toward the track junction), the clearance point will determine the usable length of sidings, loading, yard, and storage tracks.

(2) Clearance points will be marked by a 12-inch yellow bar painted on both sides of the rail base.

(3) If derails are used, they must be set to derail equipment before it reaches the clearance point.

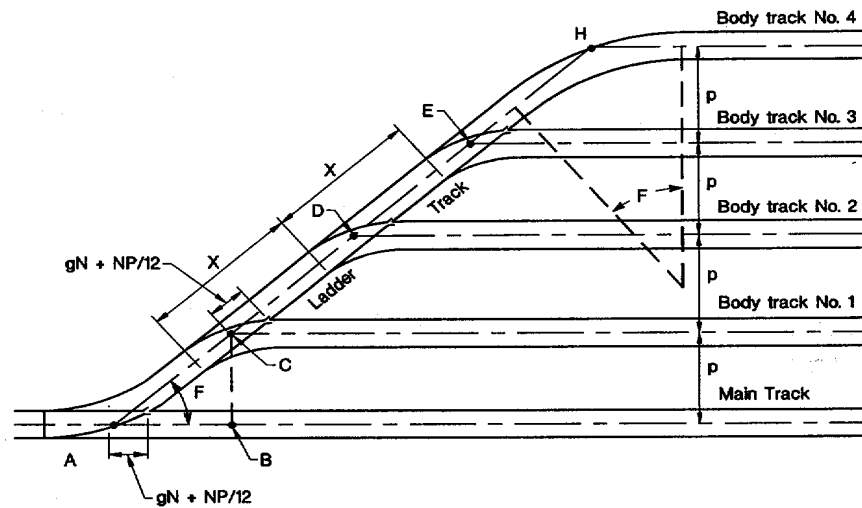
7-7. Road Crossings.

a. Crossing Location and Site Requirements.

(1) The need for, and appropriate location of, a new crossing will be checked with the installation master plan. As road crossings increase maintenance costs and safety risk, their number should be held to a minimum.

(2) Once the requirement for a road crossing is established, a study should be performed to determine the available sight distances from vehicles approaching the track and from trains approaching the crossing from either direction. (see para 6-15e.)

(3) The ideal crossing geometry is a 90 degree intersection of the track and road with slight ascending grades on the road approaches to reduce the flow of surface water toward the crossing. Conflicting superelevations often result in long-term maintenance problems and poor performance of the crossing and should be avoided.



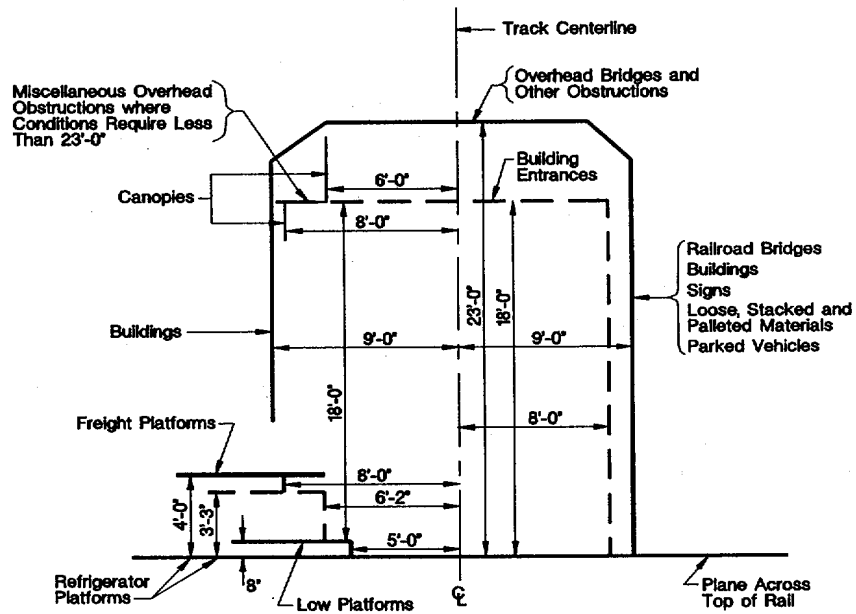
F = Frog angle.
 $gN + NP/12$ defines location of actual point of frog.
 p = distance between track centerlines.
 X = distance between points of switch.

Figure 7-5. Ladder Track Layout.

33' Overhead Wires (Exceeding 15,000 Volts)

30' Overhead Wires (750 to 15,000 Volts)

28' Overhead Wires (Incl. 750 Volts or less)



Note: Protect vertical clearances less than 23 feet and side clearances less than 9'-0" (other than track appurtenances) by an approved type of warning device.

Figure 7-6 Clearance Diagram for Tangent Track.

Table 7-4. Overhead and Side Clearances for Tangent Track.

Obstruction	Required Clearance
<u>Vertical Clearances (from top of rail)</u>	
Overhead wires: (open supply, arc wires, service drops)	
0 to 750 volts	28 feet
750 to 15000 volts	30 feet
Exceeding 15000 volts	33 feet
Other overhead wires	28 feet
Building entrances (including engine-houses)	18 feet
Overhead bridges	23 feet
Other overhead obstructions	23 feet
<u>Side Clearances (from track center)</u>	
Buildings	9 feet
Buildings without platforms (delivery required)	8 feet
Platforms:	
Freight platforms up to 4' maximum height	6 feet - 2 inches
Refrigerator car platforms up to 3' - 3"	6 feet - 2 inches
Refrigerator car platforms 3' - 3" to 4' high	8 feet
Low platforms (less than 8" high)	5 feet
Engine-house entrances	7 feet
Building entrances (other than engine-house)	8 feet
Canopies over platforms (canopy height \leq 18')	8 feet
Fences, retaining walls, utility poles, and other obstructions	feet
Bridges	9 feet
Signs	9 feet
All loose, palleted, and stacked materials	9 feet
Parked vehicles	9 feet

Note: In curves side clearances will be increased 1-1/2 inches per degree of curvature.

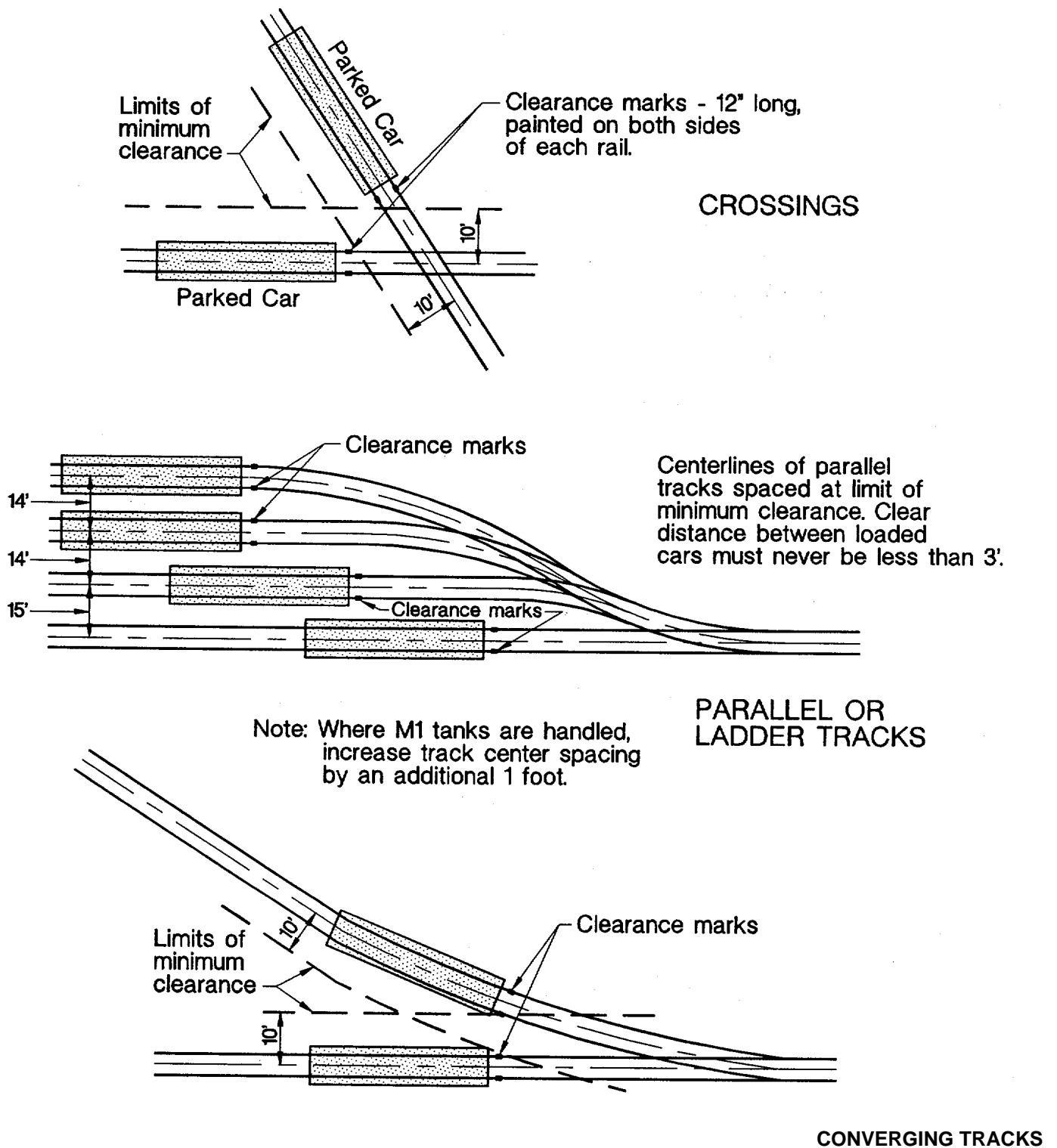


Figure 7-7 . Location of Clearance Points.